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Modeling and Calculation of Power Density from Telecommunication
Base Station Erected at Federal University Gusau in Sabon Gida,
Bungudu Local Government Area Zamfara State, Nigeria

S.B. Muhammad, M.H. Ibrahim, A. Kado, U. Yusuf, I. Abdulmumini

Department of Physics, Faculty of Science, Federal University Gusau

Corresponding Author's E-mail: ibello.muhammad@fugusau.edu.ng

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ABSTRACT

The rampant proliferation of telecommunication mast in our societies pose fear of radiation and increase the level of noise above the prescribed residential noise. Calculation of power density around ZM811B base station to a distance of 100m radius in step of 5m were made and a hypothetical human model was also used to further illustrate the effect of radiation at the so call safe radiation level adopted by African countries. The calculated power density from the distance of 5m to 50m away from the mast (ZM811B) in step of 5m were found to be within the range of $0.0000004507\mu W/m^2$ to $0.0000004507\mu W/m^2$ and from 50m to 100m in step of 10m were found to be within the range of $0.0000004507\mu W/m^2$ to $0.00000001122\mu W/m^2$. From the model, human body was found to be kept in a microwave oven for $636KW - sec/500W = 1272 = 21minutes$ per day. Nobody will put himself and his family in an open microwave oven for nineteen minutes in a day. The argument remains that the adaptation of the body to external threat and the radiation is spread over whole day. So, the simple question here to ask is would you like to put yourself in an open microwave oven for just five minutes per day, for some years? All the calculated power density were found below the safe radiation level, thus trivial. However, the model show that even at the radiation safe level one is not safe.

Keywords: power density, radiation, mast/tower, antenna, cancer.

1.0 INTRODUCTION

1.1 Introduction

The rapid development of wireless technologies (Y.Y. Jian and L.Zhang, 2020) enhance transmission and increase the number of network providers (Ziegelberger et al., 2008) worldwide. This has indeed brought a tremendous progress in all human endeavor. However, this increased electromagnetic radiation (EMR) exposure (M. Zmyślony, P. Bieńkowski, A. Bortkiewicz, J. Karpowicz, J. Kieliszek, P. Politański, 2020) which raised concern for safety (Mobilee-study et al., 2008) among the people living near telecommunication towers. (Hocking B., Gordon I. R., 1996). For example, Angskog *et al* (Member et al., 2019) warned that EMR form telecommunication gadget is considered to be a potential threat to humanity. In the same vein, Akkam *et al* (Akkam, 2020) demonstrated the effect of EMR due to base stations (BSs) on glutathione S transferase and confirmed that EMR

at radio frequency (RF) caused stress in living organism. Similarly, Singh *et al* (Singh, R.Nath, A.K. Mathur, R. S. Sharma, 2018) discussed the devastating effect of exposure to EMR at RF in short and long range and concluded that it may leads to cancer and DNA alteration. Also, Ashyap *et al* (Ashyap et al., 2020) pointed out that wave propagation around human body is interfered due to complex electromagnetic properties of the body. The interference may have an adverse effect on human health (Natarajan & Babu, 2019). Moreso, (Ashyap et al., 2021) recommended the use of High Impedance Surface (HIS) due to high conductivity of human body and protecting the body from ionizing radiation. Moreover, (Dai et al., 2021) stated that the current passing through conducting arm of an antenna give rise to electromagnetic field, whose intensity and patterns depends on antenna's geometry shape, impedance and free space. Consequently, the intensity of radiation on a given body over a particular time interval is known as

exposure (E. Regalbuto, *et al*, 2020). (Morris et al., 2015) define exposure relative to toxic environment; as the amount of the pollution imbibed or deposited on a body living within the polluted environment. And argued that exposure to EMR at RF depends on duration and intensity of the radiation on a given body. Furthermore, they described exposure and dose as inevitable parameters to environmental research. However, radiation intensity due to an obstacle (human body), from base station, changes with frequency and antenna size. EMR emanate from accelerated charge, whose field “detaches” itself, in sense and travels off at a speed of light (Batool et al., 2019) (Percuoco, 2014), carrying with it energy, momentum and angular momentum (Umbarkar et al., 2014) (Akkam, *et al* .). The EMR is divided into ionizing radiation (Carcinogen) and non-ionizing radiations (Non carcinogen) International committee on non-ionizing radiation protection (ICNIRP)1, n.d.). (L. Hardell and M. Carlberg, 2020), reported that World Health Organization (WHO) in May, 2011 identified RF radiation from 30KHZ to 300GHZ as source of ionizing radiation. Thus, RF at such range is carcinogen and dangerous to human health (P. Wiedemann and H. Schutz, n.d.). However, the degree of EMR emitted from mast depends also on the following parameters: a. number of radio channels per antenna b. power of the transmitter c. reflector shape and directivity of antenna (Penchel et al., 2019) d. type of antenna e. number of antenna on the mast (Jiang et al., 2012). Though, instability on the following variable: humidity, temperature (Rashid et al., 2021) and CO₂ may impact the results of the exposure measurements (Hansen et al., 2020). The major source of EMR in telecommunication base stations is antenna. Therefore, antenna is a device that converts electronic signals into electromagnetic wave and vice-versa with minimum loss of signal (Ceccuzzi et al., 2019). Thus, antennas are fundamental to wireless technologies and regarded as a link between transmitters and free space or free space and receivers (Cones, n.d.) (Ding et al., 2015). However, in telecommunication industries large coverage of an antenna gives effective call operation (Paffi et al., 2010). In a nut shell, the main function of antenna is to radiate electromagnetic energy (wave) in space (omnidirectional) or in a specific system of communication where high gain

and low interference is achieved (Lin & Paper, 2017). For instance, (Nakano et al., 2019) explained how the radiation steered in the azimuth direction and spread around antenna (xMeTLN system) whenever the activated metaline is changed. The radiation beam was found to spread in all diraction. Hence, the World Health Originations (WHO) warns against erecting mast at radius less than 10m away from residential areas or public centers (e.g., Schools, Hospitals, Hotels, Event centers, Museums, etc.) (Charles & Julian, 2021) (O.C.Eneh, n.d.).

1.2 Theory: Power (P_r) received or radiated by an antenna at a distance R is given by

$$P_r = P_t \times G_t \times G_r \times \left(\frac{\lambda}{4\pi R} \right)^2$$

Radiating or receiving power is directly proportional to the transmitted power, gain of transmitting and receiving antennas (Penchel et al., 2019), and square of the signal wavelength and is inversely proportional to the square of a distance R.

1.3 Radiation from the Mast (Tower)

Most of the base station antenna mounted on telecommunication mast were directional antennas with gain either 17dB or 20dB and transmission frequency range from 935 to 960 for a GSM 900 (Ding et al., 2015). This antenna had a frequency band of 25MHz which was divided into twenty sub-band of 1.2MHz, allotted to various operator. Of cause, there were many carrier frequencies allocated to one operator with upper limit of 6.2MHz band width. Each carrier frequency might transmit 10 to 20W of power. Thus, one operator might transmit 50 to 100W of power and there might be more than one operator on a tower. For two or three operators 200 to 300W is transmitted (To & By, 2010) (Dai et al., 2021). For many operators, huge KW of power was expected to be transmitted especially at the main lobe direction. The mast (ZM00811) (see plate 1) in Federal University Gusau, Sabon-gida host MTN services. Therefore, two radio frequency (RF) antennas and six (6) micro wave (MW) antennas (see plate 1) were mounted on the mast. The power density in this area would as well increase accordingly.

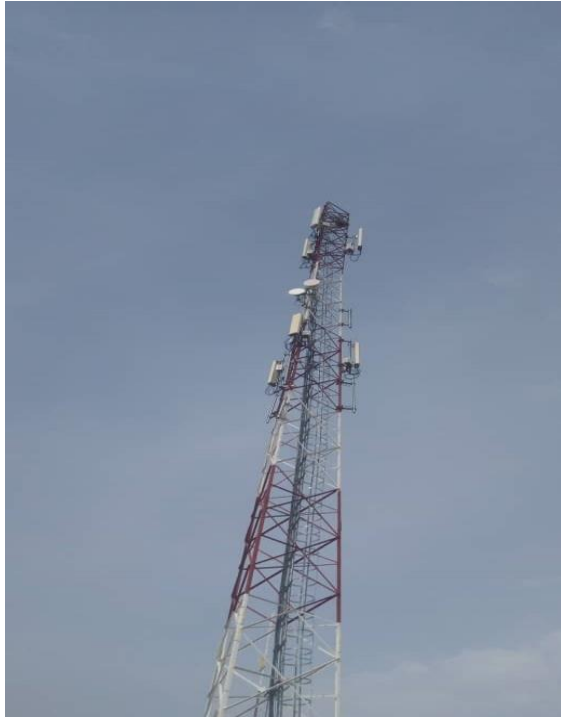


Plate 1: The mast (ZM00811) in Federal University Gusau, Sabon-gida host MTN services

1.4 Radiation Norms Adopted in Nigeria

Though, there is no clear radiation norms specify by Nigeria communication commission (NCC) or NESREA, most African and Asian countries adopted 1998 guidelines issued by International Committee on Non-ionizing Radiation Protection (ICNIRP) for safe power density of $\frac{f}{200}$. Where f is a frequency in MHz. For GSM 900 transmitting band (935 – 960 MHz), power density is $4.7W/m^2$ and GSM 1800 transmitting band (1810 – 1880 MHz), power density is $9.2W/m^2$ (To & By, 2010). The guideline shows that the sum of all radiation is taken into cognizance for concurrent exposure to multiple frequencies in a field. We often consider only one carrier frequency other than the total number of transmitters in that area, which will by far exceed the ICNIRP limit. People living near (not quite close) the tower are steadily exposed to radiation 24hrs in a day. There is less radiation emitted vertically down ward compared to horizontal radiation. Though, the radiation is inversely proportional to square of distance. The two important parameters mostly considered were intensity and duration, with sufficient time (ten years and above) the radiation may cause damage to living organism (Miura et al., 2021).

2.0 MATERIALS AND METHOD

2.1 Materials

The following were the materials used in this research work: Mast, transmitters, RF -antennas, Mw-antennas, cell phones

2.1.1 Parameters measured

The parameters measured in this research were; in this research are Transmitting power, Gain of transmitting antenna, operations frequency,

2.1.2. Description of the Study Area

Federal University Gusau is located at Latitude 12.13497 and longitude 6.78558 in Sabon-Gida along Zaria-Gusau Road. There is only one mast located in this area, which is erected within the University premises. The mast with the site number ZM811B was erected about 7 years ago. Being isolated in an open place, it may not pose a serious threat.

2.2. METHOD

2.2.1. Determination of the Study Population

The criteria for inclusion were people living or working, public centers (Schools, Mosque etc.) within 100 meters in radius around the mast. There were no houses around the mast and thus, no sample size was determined.

2.2.2. Sampling Method is Subject Selection

A multi – stage sampling techniques was not employed because there was no population around the mast (stood in an open space) as at the time of this research work.

2.3. Calculation of Power Density

Power density is the power received or absorbed by human body from a source of radiation.

Power density at distance R is giving by

$$P_d = \left(\frac{P_t \times G_t}{4\pi R^2} \right) \text{ Watt}/m^2$$

Where P_t – Transmitter power in watt

G_t – Gain of transmitting antenna

P_d – Power density

Plate I: Mast 811B with six micro wave and two

The above formular was used in calculating radiation power density from the mast to a distance

of 50m in step of 5m and from 50m to 100m in step of 10m. There were no houses around the mast, so couldn't deployed questionnaire to get any information.

2.4. Model

A human body was model as a cylinder and the safe radiation level of 4.7W/m² was used in calculating power density a human body would be subjected to per day.

2.4.1. Theoretical Consideration of The Model

Human body absorbed radiation, whenever exposed to EM field, because of its large water content about 70%. The process is the same as that of cooking food, in microwave oven, in which the water content of the food will heat up first. Radiation effects manifested easily around the part of the body that contained more liquid such as heart, eye, abdomen, joints, brain. So, when the liquid began to heat up, it will thicken and become sticky. This results in drying up of the fluid at those parts of human body, that supposed to have high liquid content. Thus, the effect of radiation will become more glaring in those areas of the affected person. The wavelength of the cell mast transmitting frequency is not in any way comparable to human size, thus, multiple resonances will occur on the exposed body and cause heating, which will eventually raise the body temperature permanently(Busari & Awodele, 2009).

3.0 RESULT AND DISCUSSION

3.1 Results

Power density measured at ZM811B for a distance of 100m away from the mast. From 5m to 50 away in steps 5m and from 50 to 100m away in steps of 10m and the result is expressed both in Weber per metre square and Micro-Weber per metre square as shown in table 1

Table1: Calculated power density at various distances from ZM811B mast.

| S / N | Distance (m) | Power density (W/m ²) | Power density (μW/m ²) |
|-------|--------------|-----------------------------------|------------------------------------|
| 1 | 5 | 0.4507 | 0.0000004507 |
| 2 | 10 | 0.1127 | 0.0000001127 |
| 3 | 15 | 0.05008 | 0.00000005008 |
| 4 | 20 | 0.02817 | 0.00000002817 |

| | | | |
|----|-----|----------|----------------|
| 5 | 25 | 0.01801 | 0.00000001801 |
| 6 | 30 | 0.01257 | 0.00000001257 |
| 7 | 35 | 0.009199 | 0.000000009199 |
| 8 | 40 | 0.007043 | 0.000000007043 |
| 9 | 45 | 0.005565 | 0.000000005565 |
| 10 | 50 | 0.04507 | 0.00000004507 |
| 11 | 60 | 0.003130 | 0.000000003130 |
| 12 | 70 | 0.002300 | 0.000000002300 |
| 13 | 80 | 0.001761 | 0.000000001761 |
| 14 | 90 | 0.001391 | 0.000000001391 |
| 15 | 100 | 0.001122 | 0.000000001122 |

3.2 Discussion

The results obtained in this research showed that non-ionizing radiation from the telecommunication mast (ZM11B) are much below ICNIRP standard and thus, trivial. However, there were no population around the mast as at the time of this research work. So, there was no further observation made as to the assessment of radiation,

Power density is the power received or absorbed by living organism due to radiation. Calculated power density at variable distance from the mast (ZM811B) at FUGUS in Sabon-gida is shown in table3. The calculated power density shown on the table3 was for single antenna. However, there were six micro wave (MW) antennas and two radio frequency (FR) antennas on the mast. Though, the calculated power density at closest distance was 5m away and continues up to 50m in steps of 5m, with power density range [0.0000004507μW/m² to 0.0000004507μW/m²], and from 50m to 100m in step of 10m with a power density range [0.0000004507 μW/m² to 0.00000001122 μW/m²]. All the calculated power densities were very low even when multiplied by two (2) compared to ICNIRP standard adopted by African's countries (4.7W/m²).

3.3 Modeling

Let us evaluate microwave power per human body if exposed to so called safe radiation level adopted by African countries. The power density: 4.7 W/m² for GSM 900 band is consider to be safe

radiation level in Nigeria. If we take human body as a cylinder then its area will be 1.564 square metre (average height 5'7" = 1.77m and waist 34" = 0.86m). Power received by human body is power density times area = 7.35Watt. In one hour, microwave energy absorbed is $7.35 \times 3600 = 26.5\text{KW-sec}$. In twenty-four hours, energy absorbed is $26.5 \times 24 = 636\text{KW-sec}$. A typical microwave oven has rating of 700 to 1000W with 60% efficiency, microwave power output is approximately 500W. This indicate that human body can be safely kept in a microwave oven for $636\text{KW} - \text{sec}/500\text{W} = 1272 = 21 \text{ minutes}$ per day. Nobody will put himself and his family in an open microwave oven for twenty-one minutes in a day. The argument remains that the adaptation of the body to external threat and the radiation is spread over whole day. So, the simple question here to ask is would you like to put yourself in an open microwave oven for just five minutes per day, over years? This was for single operator. For many operators, it will double accordingly.

4.0 CONCLUSIONS

The calculated power densities at various distance were found below the ICNIRP standard adopted by African and Asian countries. However, From the model, human body would be subjected to heating similar to that of microwave oven for $636\text{KW} - \text{sec}/500\text{W} = 1272 = 21\text{minutes}$ per day. Nobody will put himself in an open microwave oven for twenty-one minutes in a day. This indicate that even at the safe level of radiation one is not safe.

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6.0 RECOMMENDATION

More research should be conducted as regard to EMR at all frequencies. However, variables such as humidity, CO₂, and temperature should be monitored during the exposure measurement especially when performing *in vitro* exposures, as variation in humidity, CO₂, and temperature could

induce stress on a subject, which could impact results.

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